DOCUMENT RESUME

ED 287 223 EC 200 528

AUTHOR Geary, David C.; And Others
TITLE Cognitive Addition: Comparison of Learning Disabled and Academically Normal Children.
PUB DATE Apr 87
NOTE 16p.; Paper presented at the Biennial Meeting of the Society for Research in Child Development (Baltimore, MD, April 23-26, 1987).
PUB TYPE Speeches/Conference Papers (150) -- Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Addition; *Cognitive Processes; Computation; Elementary Education; Elementary School Students; *Learning Disabilities; *Learning Strategies; *Mathematics Achievement; Memory; Number Concepts; Problem Solving; Self Evaluation (Individuals)

ABSTRACT

To isolate the process deficits underlying a specific learning disability in mathematics achievement, 77 academically normal and 46 learning disabled (LD) students in second, fourth or sixth grade were presented 140 simple addition problems using a true-false reaction time verification paradigm. (The problems were on a video screen controlled by an Apple II+ computer.) Regression models indicated that the majority of normal and LD second grade subjects used an implicit counting strategy for problem solution. However, LD subjects required a greater amount of time to execute this task and appeared to be deficient in the ability to self-monitor the problem solving process. A shift from reliance on the counting strategy to a memory retrieval process from the second to sixth grade was evident for normal subjects, but not for LD subjects, the majority of whom relied on the counting strategy throughout the elementary school years. (Author/CL)

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Cognitive Addition: Comparison of Learning Disabled and Academically Normal Children

David C. Geary
University of Texas at El Paso

Todd D. Little, Keith F. Widaman
University of California at Riverside

Pierre Cormier
Acadia University

Presented at the biennial meeting of the Society for Research in Child Development, Baltimore, Maryland, April 1987.

An extended version of this paper will be published in Cognitive Development.

Correspondence should be addressed to:

David Geary
Department of Psychology
University of Texas
El Paso, TX 79968

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Abstract

Simple addition problems were presented using a true-false RT verification paradigm to 77 academically normal and 46 learning disabled (LD) subjects in the second, fourth, or sixth grade. This information-processing paradigm was used to determine the process deficits associated with a learning disability in mathematics achievement. Regression models indicated that the majority of normal and LD second grade subjects used an implicit counting strategy for problem solution. However, LD subjects required a greater amount of time to execute this algorithm and appeared to be deficient in the ability to self-monitor the problem solving process. A shift from reliance on the counting strategy to a memory retrieval process from the second to sixth grade was evident for normal subjects. No such shift was evident for LD subjects, as the majority of these subjects relied on the counting strategy throughout the elementary school years.

Aims

The aim of the study was to isolate the process deficits underlying a specific learning disability in mathematics achievement during the elementary school years.

Method

Subjects. The subjects were 77 academically normal children and 46 learning disabled children in the second, fourth, or sixth grade. The LD subjects were classified based on local school district criteria. Specifically, students scoring below the 34th percentile on the mathematics section of the Stanford Achievement Test were diagnosed as having a specific learning disability in mathematics achievement. All 46 LD subjects attended general education classes for most of their school day, but received remedial services in the form of three hours per week of specialized instruction on basic number concepts and arithmetic skills. None of the LD children received remedial services in any other academic area.

Reaction Time Stimuli

Stimuli consisted of 140 simple addition problems. Each of the addition problems consisted of two vertically placed single-digit intergers presented with a stated sum. Seventy of the problems were selected from the "basic 100" pairwise combinations of the

integers 0 through 9, and were presented with a correct stated sum. Across the 70 problems, each integer 0 through 9 appeared seven times as the first addend and seven times as the second addend. The remaining simple addition problems were the same 70 pairs of addends, but were presented with a stated sum incorrect by ± 1, or ± 2. The magnitude of the error was counterbalanced across the 70 false stimuli. No repetition of either integer or of the stated sum was allowed across consecutive trials, and no more than four consecutive presentations of true or false problems were allowed.

Apparatus

The arithmetic problems were presented at the center of a 30 cm X 30 cm video screen controlled by an Apple II + microcomputer. A Cognitive Testing Station clocking mechanism ensured the collection of RTs with ± 1 msec accuracy. Subjects were seated approximately 70 cm from the video screen and responded true by depressing a button on the side of their dominant hand and responded false using their non-dominant hand.

For each problem, a READY prompt appeared at the center of the video screen for a 500 msec duration, followed by a 1,000 msec period during which the screen was blank. Then, an arithmetic problem appeared on the screen and remained until the subject responded, at which time the problem was removed. If the subject responded correctly, the screen was blank for a 1,000

msec duration, and the READY prompt for the next problem appeared. If the subjects responded incorrectly a WRONG prompt with a 1,000 msec duration followed the removal of the stimulus and preceded the 1,000 msec interproblem blank period.

Procedure

Subjects were tested individually in a quiet room on school grounds and during school hours. Subjects were told they were going to be presented with four sets of addition problems, with 35 problems in each set. We told subjects that their task was to respond true or false to each presented problem by pressing the appropriate button. Equal emphasis was placed on speed and accuracy. Subjects were presented with 10 practice problems prior to the presentation of the first set of stimuli, and were given a two-minute rest period between the presentation of each of the problem sets. The entire testing session lasted approximately 30 minutes.

Results

Models for mental addition were fit to average RT data using hierarchical regression techniques. Structural variables for the search/compute process included variables for the five counting-based models proposed by Groen and Parkman (1972), the correct-sum-squared (sum^2; Ashcraft, 1982), and the correct product (prod; Miller, Perlmutter, & Keating, 1984).

The sum^2 and prod variables represent a retrieval process, whereby an answer is retrieved from a long-term memory network of arithmetic facts. The substantive counting process used by elementary school children is represented by the min structural variable (the smaller of the addend or augend). The process consistent with the min variable involves setting an internal counter to the cardinal value of the larger addend and then incrementing, by ones, the counter a number of times equal to the smaller addend until a sum is obtained. The slope value for min estimates the time required to increment, by ones, the counter. The process represented by min is most likely an implicit speech strategy (Kaye, Post, Hall, & Dineen, 1986).

Subjects at each grade level were divided into two groups based on the value of the min slope estimate, "fast" processors and "slow" processors. "Slow" processors had min slope estimates above the implicit counting rate per incrementation for their grade level,

whereas "fast" processors had a min slope estimate below the implicit counting rate (a cluster analysis confirmed these classifications). "Slow" processors appeared to be implicitly counting to solve addition problems, whereas "fast" processors appeared to relie on memory retrieval for problem solution. Figures 1 and 2 graphically present average RT as a function of min for "slow" and "fast" processors at each grade level. The rather erratic performance of the "slow" processor second grade LD subjects is consistent with previous findings (Svenson & Broquist, 1975) and suggests that these LD subjects were inconsistent in the selection of the strategy invoked for problem solution. It should also be noted that the second grade LD subjects had a rather high error rate (considering they used a reliable counting algorithm for problem solution) of 13.0%.

Table 1 presents the frequency of subjects classified as "fast" or "slow" processors across grade level and academic status. For second grade subjects there was no significant difference in the frequency of normal and LD subjects classified as "fast" or "slow" processors, $\chi^2 = 0.07$, $> .25$. However, significantly more LD subjects were classified as "slow" processors for both the fourth grade, $\chi^2 = 6.33$, $p < .05$, and the sixth grade, $\chi^2 = 5.20$, $p < .05$.

Finally, a series of combined regression models were specified so that differences in the magnitude of

the slope estimate for the min and prod variables, for "slow" and "fast" processors respectively, could be tested statistically comparing same grade LD and normal children. The results of these procedures indicated that the min slope estimate for second grade LD subjects was significantly larger than the min slope for normal second grade subjects, F (1,122) = 21.83, p < .001. No other substantive comparison reached statistical significance (all p's > .05).

Conclusions

1. Across the elementary school years, LD and normal children differ in terms of the developmental maturity of the component process (counting or memory retrieval) invoked for the solution of addition problems. Learning disabled subjects appear to relie on the less mature counting algorithm for problem solution, whereas normal children shifted from the counting to the memory retrieval strategy, across the elementary school years.
2. Second grade LD children required a greater amount of time to execute the counting algorithm (per incrementation) that did normal second grade children who appeared to use the same strategy.
3. The second grade LD children appeared to be rather variable and inefficient in strategy selection and appeared to have a deficit in the ability to monitor the problem solving process.

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Table 1

Frequency of Subjects Classified as Fast or Slow Processors Across Grade Level and Academic Status

	Grade 2		Grade 4		Grade 6	
Group	Normal	LD	Normal	LD	Normal	LD
Fast	10	3	16	1	12	6
Slow	18	6	15	13	6	17

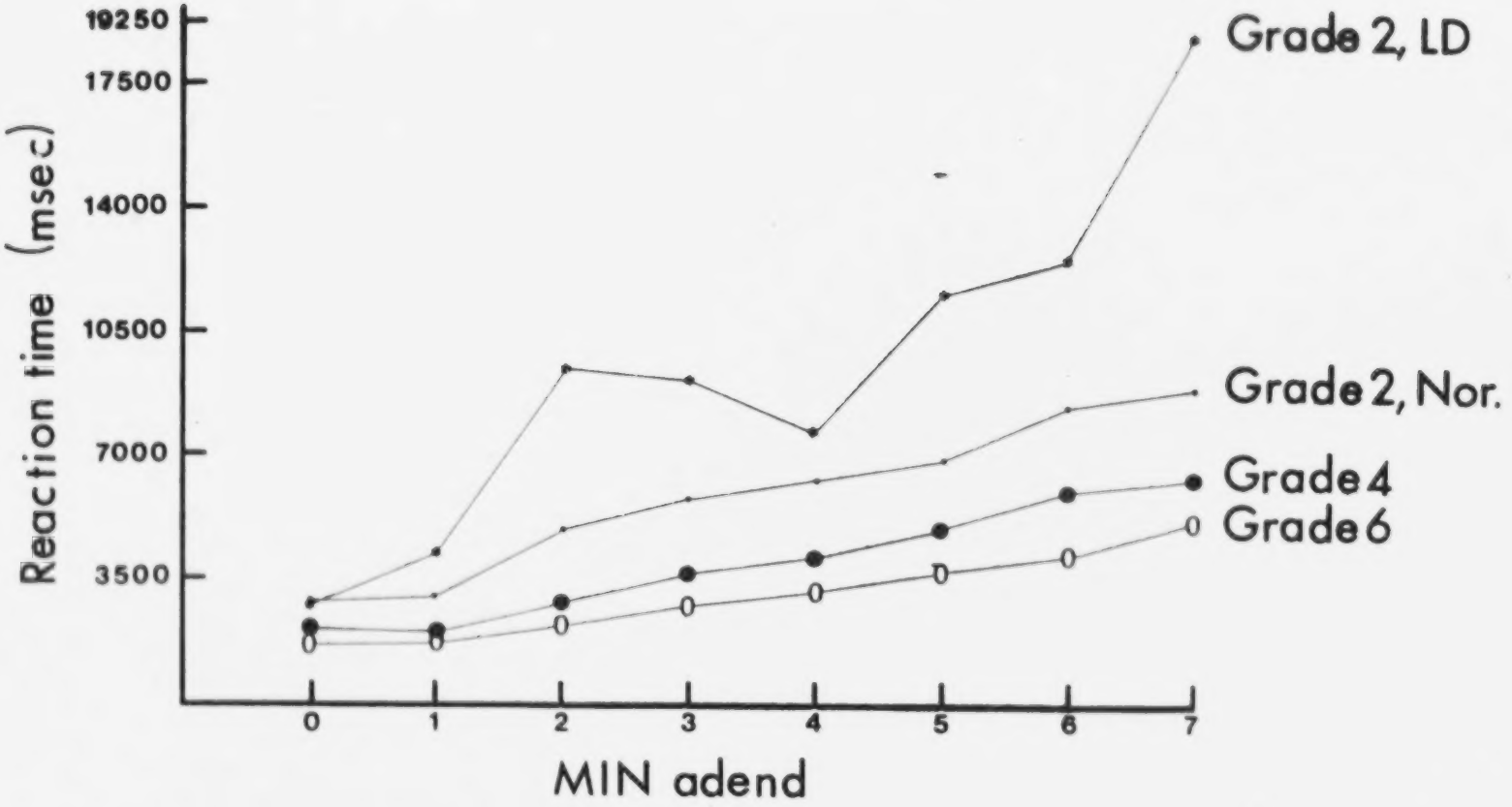

Figure 1: Mean "slow processor" reaction time as a function of grade, academic status, and MIN addend for true non-tie problems.

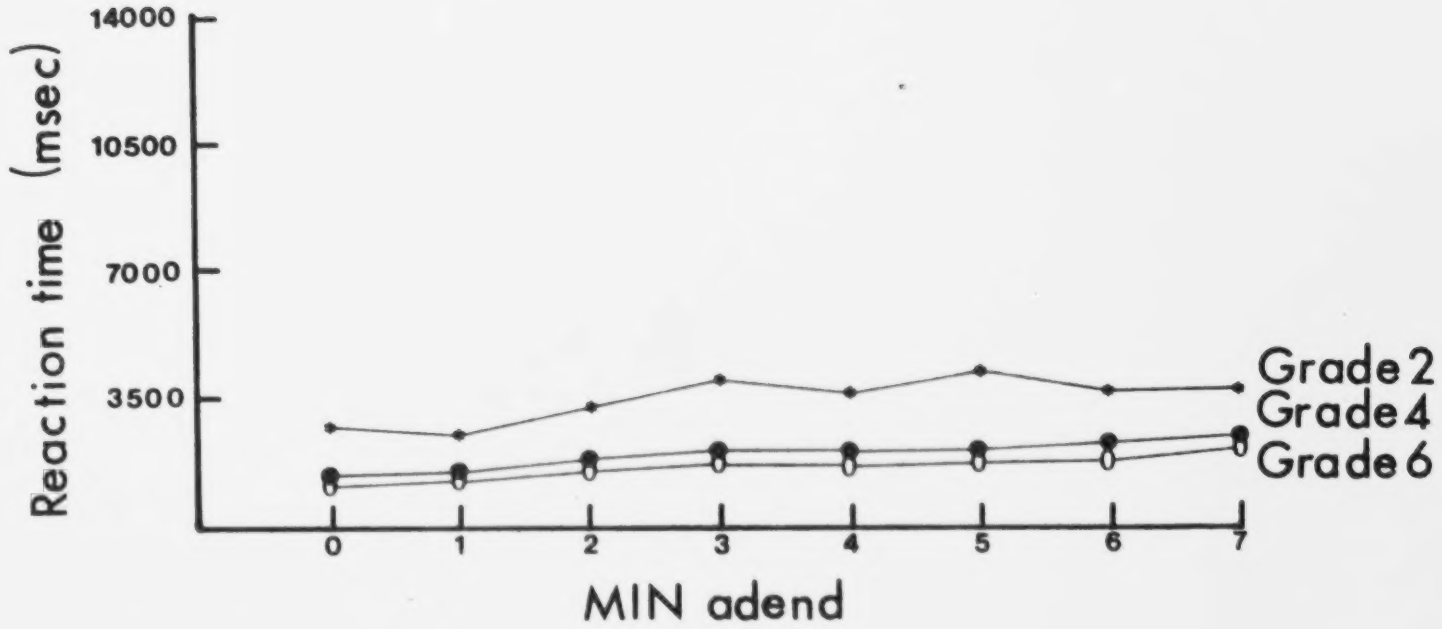

Figure 2: Mean "fast processor" reaction time as a function of grade and MIN addend. Second and fourth grade means are for normal subjects only, due to the small number of second and fourth grade "fast processors". For the sixth grade, LD and normal "fast processor" subjects did not differ significantly, therefore these means were collapsed and a single trend presented.